

## Percutaneous fiducial marker placement under CT fluoroscopic guidance for stereotactic body radiotherapy of the lung: an initial experience

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The aim of this study is to describe our initial experience with the VISICOIL, which is the first percutaneous fiducial marker approved for stereotactic body radiotherapy in Japan, and to evaluate its technical and clinical efficacy, and safety. Eight patients underwent this procedure under CT fluoroscopic guidance. One patient had two tumors, so the total number of procedures was nine. We evaluated the technical and clinical success rates of the procedure and the frequencies of complications. Technical success was defined as when the fiducial marker could be placed at the target site, and clinical success was defined as when stereotactic body radiotherapy could be performed without the marker dropping out of position. The technical success rate was 78% (7/9). In one of the two failed cases, we aimed to place the marker inside the tumor, but misplaced it beside the tumor. In the other failed case, we successfully placed the marker beside the tumor as planned; however, the marker migrated to near the pleura after the patient stopped holding their breath. None of the markers dropped out of place, so the clinical success rate was 100% (9/9). The complication rates were as follows: pneumothorax: 56% (5/9), pneumothorax necessitating chest tube placement: 44% (4/9), focal intrapulmonary hemorrhaging: 67% (6/9), hemoptysis: 11% (1/9), mild hemothorax 11% (1/9), air embolism 0% (0/9), and death 0% (0/9). In conclusion, this new percutaneous fiducial marker appears to be useful for stereotactic body radiotherapy due to its good stability.

**Keywords:** fiducial marker; CT fluoroscopic guidance; SBRT; percutaneous

### INTRODUCTION

Stereotactic irradiation is a well-established treatment for intracranial neoplasms [1, 2], and it has also become an indispensable treatment modality for Stage I non-small-cell lung cancer (NSCLC) patients who refuse surgery or have medically inoperable tumors [3, 4]. Furthermore, it has been reported that not only NSCLC but also small lung metastases and small-cell lung cancer can be successfully treated with stereotactic body radiotherapy (SBRT) [5, 6]. Since lung tumors can move due to respiration, cardiac motion, and aortic pulsation, managing tumor motion is very important for further refining the technique. The insertion of fiducial markers using bronchofiberscopy has been

attempted, but it has been reported that the markers frequently drop from their initial positions [7, 8]. Recently, the percutaneous insertion of fiducial markers has been reported [9–11], but experience with them is still limited. The VISICOIL (SCETI Medical Labo K. K., Tokyo, Japan) is the first fiducial marker to be approved for percutaneous insertion in Japan. In this study, we describe our initial experience with this new fiducial marker and evaluate its technical feasibility, clinical efficacy, and safety.

### MATERIALS AND METHODS

This study was approved by the institutional review board, and written informed consent was obtained from all

patients. Between October 2011 and April 2012, eight patients underwent percutaneous fiducial marker placement under CT fluoroscopic guidance for lung tumors before SBRT at two hospitals. The patients included five men and three women. Their median age was 76 years (range, 55–83 years), and all of them were inpatients. One patient had two tumors; thus, the total number of procedures was nine. All tumors were pathologically or clinically diagnosed as malignant lung tumors.

### **Percutaneous fiducial marker placement technique**

All patients underwent diagnostic CT scans of their chest involving 3–5 mm-thick contiguous axial tomographic sections before undergoing marker placement. During the procedure, preliminary helical CT scan images (section thickness: 3 mm) of the tumor were obtained. Then, after reviewing these preliminary images, the patient's position, the needle entry site, and the direction of the approach were planned to determine the most appropriate route for the needle, i.e. the route that traversed the least amount of aerated lung tissue and avoided bullae and fissures. All patients received supplemental nasal oxygen, and their vital signs, including their heart rate, blood pressure, respiratory rate and ECG, were monitored. Localization was performed using CT, lasers and a grid system. Local anesthesia was achieved via the subcutaneous administration of 1% lidocaine. All procedures were performed with a 17- or 18-gauge coaxial introducer needle containing a VISICOIL linear fiducial marker during breath-holding under CT fluoroscopic guidance. If necessary, the CT gantry was angled to avoid blood vessels, fissures and ribs.

The size of the fiducial marker, which affects its visibility, depended on the radiation therapy equipment at the two hospitals. One machine (linear accelerator) required a 17-gauge needle and a marker that measured 1.1 mm in diameter and 5 mm in length, and the other (CyberKnife) required an 18-gauge needle and marker that measured 0.75 mm in diameter and 5 mm in length. The imaging parameters during CT fluoroscopy included a CT beam width collimated to 3 mm. After confirming that the needle tip had reached the lesion, the fiducial marker was deployed, and the needle was removed. After the procedure, CT was performed to determine the presence of complications such as pneumothorax. When moderate or severe pneumothorax was detected, a chest tube was installed. Each patient was admitted to the hospital on the day of the procedure and discharged from the hospital the next day (two days hospitalization) if there were no complications.

### **Evaluation of the success rate and complications**

Technical success was defined as when the fiducial marker could be placed at the intended site. The target site was chosen by consensus by one interventional radiologist and one radiation oncologist before the procedure. We tried to

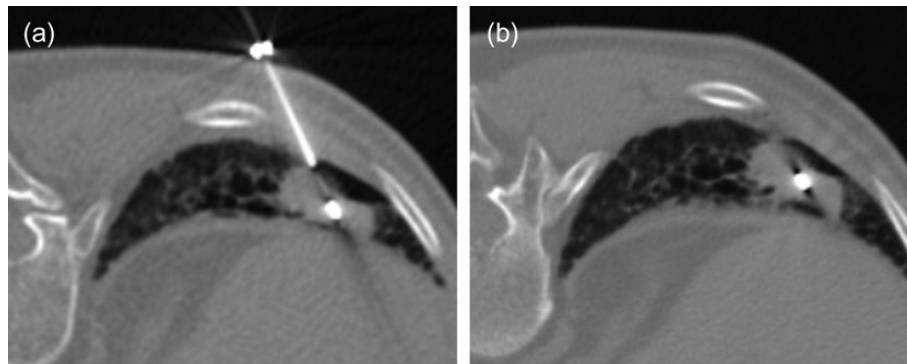
place one fiducial marker inside each tumor. However, in cases in which this was difficult because of the size of the tumor, we attempted to place a marker either side of the tumor to sandwich it. Clinical success was defined as when SBRT could be performed without the marker dropping out of position. The following complications were evaluated: pneumothorax, pneumothorax necessitating chest tube placement, pulmonary hemorrhaging, hemoptysis, hemothorax, air embolism and death.

## **RESULTS**

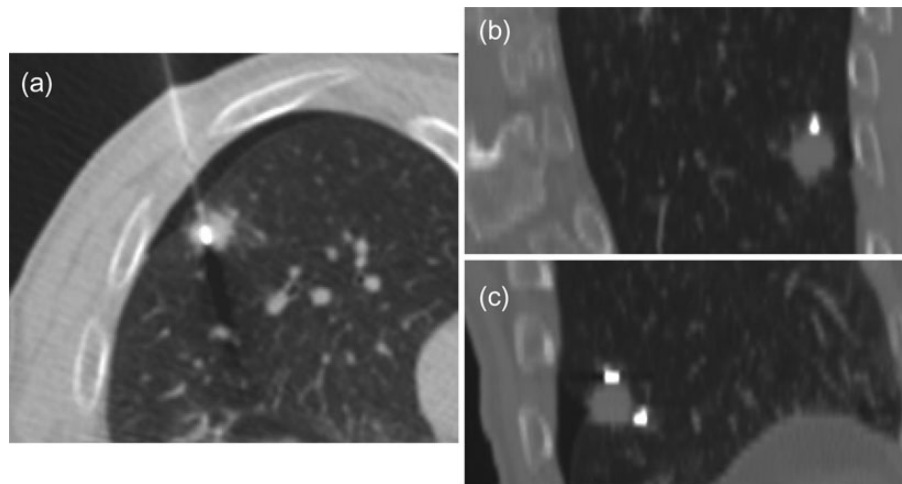
The median tumor size was 22 mm (range, 13–34). The tumor location was as follows: the right upper lobe in three cases (33%), the right lower lobe in three cases (33%), the left upper lobe in one case (12%), and the left lower lobe in two cases (22%). The tumor diagnosis was primary lung tumor in six cases (67%) and metastatic lung tumor in two cases (22%). In the remaining patient, it was difficult to determine whether the tumor was primary or metastatic from its pathological findings. The target sites for marker insertion were as follows: inside the tumor in four cases (44%) and around the tumor (to sandwich the tumor) in five cases (56%). The fiducial marker placement was successful in seven procedures (78%, Fig. 1) and failed in two procedures (22%). Thus, the technical success rate was 78% (7/9). In one of the two failed cases, we aimed to place the marker inside the tumor, but misplaced it beside the tumor. So, we changed our plan and placed another marker on the opposite side of the tumor to sandwich it (Fig. 2). In the other failed case, we were able to place the marker beside the tumor, as we had aimed; however, after the patient stopped holding their breath, the marker migrated to near the pleura (Fig. 3). We confirmed that it had not dropped into the thoracic cavity and that the position of the marker was acceptable for SBRT.

SBRT was successfully performed in all nine procedures, and none of the markers dropped out of position. Thus, the clinical success rate was 100% (9/9). SBRT was usually started two weeks after the marker insertion. In four of five cases developing pneumothorax, SBRT was started as planned because pneumothorax was cured in a few days. In the remaining patient, however, SBRT was delayed by one week due to prolonged treatment of pneumothorax. Treatment planning CT confirmed disappearance of the pneumothorax in all cases. The median hospitalization period was 3 days (range, 2–9).

The complication rates were as follows: pneumothorax: 56% (5/9), pneumothorax necessitating chest tube placement: 44% (4/9), focal intrapulmonary hemorrhaging: 67% (6/9), hemoptysis: 11% (1/9), mild hemothorax: 11% (1/9), air embolism: 0% (0/9), and death 0% (0/9).



**Fig. 1.** An 80-year-old man presented with a 32-mm primary lung carcinoma in the right lower lobe. **(a)** CT shows a 17-gauge needle and a marker measuring 0.75 mm in diameter and 5 mm in length. The needle was used to puncture the tumor under CT fluoroscopic guidance. **(b)** CT showed that the fiducial marker had been successfully placed inside the tumor.

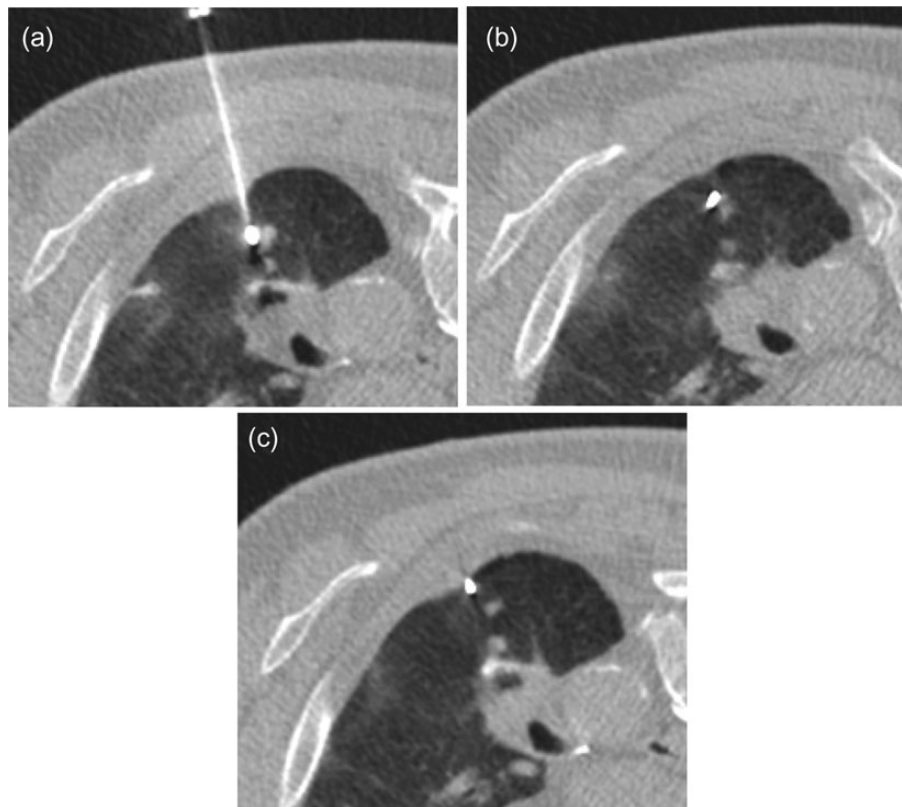


**Fig. 2.** An 85-year-old man presented with an 18-mm primary lung carcinoma in the left lower lobe. **(a)** We aimed to place a marker inside the tumor. CT shows an 18-gauge needle and a marker measuring 1.1 mm in diameter and 5 mm in length. The needle was used to puncture the tumor under CT fluoroscopic guidance. **(b)** Coronal CT image showing that the marker was not placed inside the tumor but rather was placed beside it. **(c)** Thus, we decided to place another marker on the other side of the tumor in order to sandwich it, and a sagittal CT image shows the two markers beside the tumor.

## DISCUSSION

There are several approaches to dealing with tumor motion in SBRT for lung tumors. They can be classified into two major types [12]. One type of approach is to minimize the tumor motion using inhalation of oxygen, abdominal compression, learning of regular respiratory patterns, or a breath-hold technique [13–16]. However, these methods are generally associated with modest efficacy and/or poor reproducibility. Moreover, some patients with poor pulmonary function, as included in the current study, cannot hold their breath even for a few seconds, and some patients

cannot learn their respiratory pattern sufficiently. The other type of approach, which is more sophisticated, is target-gating or target-chasing, in which the movements of the skin surface or other markers are monitored [17–21]. While monitoring the respiratory movement, imaging the tumor position during irradiation using fiducial markers like VISICOIL should be the most straightforward method. We inserted the fiducial markers for tumor-tracking SBRT with a new version of Cyberknife (G4), and also for SBRT with a linear accelerator using abdominal compression; we used the fiducial markers to improve the localization accuracy.



**Fig. 3.** A 67-year-old man presented with a 13-mm primary lung carcinoma in the left lower lobe. (a) We aimed to place a marker either side of the tumor in order to sandwich it. CT shows an 18-gauge needle and a marker measuring 1.1 mm in diameter and 5 mm in length. The needle was used to try to place a marker beside the tumor under CT fluoroscopic guidance. (b) CT shows that the marker was successfully placed beside the tumor. (c) However, after the patient stopped holding their breath, the marker migrated to near the pleura, as shown by CT. The marker was observed and fortunately did not drop into the thoracic cavity.

The respiratory-gating method has been used in particle therapy for >10 years with encouraging results [22]. However, it has been suggested that respiration depth is not always consistent with skin movement [23]. Thus, the insertion of fiducial markers using bronchofiberscopy has recently been attempted for setup and tumor tracking in radiotherapy for lung tumors [7, 8]. However, Harada *et al.* [7] reported that 26% (5/19) of markers placed by bronchofiberscopy had dropped out of position by the end of the radiation therapy. Furthermore, Imura *et al.* [8] reported that 24% (37/154) of markers inserted by bronchofiberscopy had dropped by the beginning of radiation therapy, and 25% (39/154) had dropped by the end of radiation therapy. On the other hand, a few authors have reported their experiences with percutaneous fiducial marker placement, and de May *et al.* [9] reported that none of their percutaneously inserted markers dropped out of position. However, Kothary *et al.* [10] reported that 9% (4/44) of percutaneously inserted markers migrated into the thoracic cavity. In our study, no markers dropped into the thoracic cavity, and

SBRT was performed successfully. In one case, however, we experienced slight migration to near the pleura during the procedure. Thus, we think that the fiducial marker displays better stability in the lungs than markers placed by bronchofiberscopy, although it is necessary to pay attention to the risk of migration into the thoracic cavity, especially for tumors located near the pleura.

In one of our procedures we attempted to puncture the tumor, but it was difficult to penetrate it and we misplaced the fiducial marker beside the tumor. We used an 18-gauge needle for this procedure. In our experience, this needle is not sharp enough, and it might be more difficult to penetrate the pleura or tumor with this needle than with a biopsy needle. Furthermore, we think this might be the reason for the high complication rates, especially the frequency of pneumothorax. Pneumothorax occurred in 56% (5/9) of our cases, which is higher than the previously reported frequency for percutaneous marker insertion [9–11]. Thus, we think the sharpness of the needles used for this procedure should be improved. In one of our cases,



SBRT was delayed because of prolonged pneumothorax. We recommend that when pneumothorax occurs, a chest tube should be inserted as soon as possible.

In this study, we initially attempted to place the marker inside the tumor, as reported previously [9–11]. However, it was difficult to puncture some tumors, especially small tumors so several puncturing attempts were needed, which might have increased the risk of pneumothorax. Moreover, puncturing a tumor can result in tumor cell dissemination, although the frequency of this complication is low; it has been reported to be 0.04% in CT-guided biopsy for lung tumors [24]. Thus, we think that it might be better to place a marker either side of the tumor to sandwich it.

## CONCLUSION

In conclusion, we think the new percutaneous fiducial marker is useful because of its good stability, but it is necessary to pay attention to the possibility of migration and the high risk of pneumothorax. On the basis of our results, we are unable to discuss the local control rate of patients undergoing SBRT with the fiducial marker due to the short follow-up periods involved. It will be necessary to observe our patients for a longer period to evaluate the clinical usefulness of this marker.

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